J. Dairy Sci. 84:1822–1828

Tail-Docking Alters Fly Numbers, Fly-avoidance behaviors, and Cleanliness, but not Physiological Measures

S. D. Eicher,* J. L. Morrow-Tesch,*,† J. L. Albright,‡ and R. E. Williams§
*USDA-ARS, Livestock Behavior Research Unit,
216 Poultry Bldg., Purdue University, West Lafayette, IN 47907
†Present Address: USDA-ARS, Livestock Issues Research Unit, Animal Science Bldg.,
Texas Tech University, Lubbock, TX 79409-2141
‡Department of Animal Sciences, 103 Poultry,
§Department of Entomology, Entomology,
Purdue University, West Lafayette, IN 47907

ABSTRACT

Tail docking is an animal well-being issue not only regarding the docking procedures but also because of concerns during fly season. To address the latter question, we selected eight cows that had been tail-docked in a previous experiment and eight nondocked cows matched by stage of lactation. Physiological, immunological, and behavioral measures were used to evaluate the well being of those cows housed in a tie-stall barn during fly season for 5 consecutive days. Behavior was observed for 5-min interval instantaneous scan samples for 1 h each at 0800, 1200, and 1600 h. Flies were counted before behavior observations. Blood samples were taken daily for plasma and leukocyte separation. Cows were scored on d 5 for cleanliness on a five-point scale. Docked cows were cleaner, but fly counts of docked cows were greater for total fly counts and rear leg counts. However, counts were not different on front legs. Time of day was significant, so each time of day was analyzed separately. Docked cows were observed to exhibit fewer tail swings at 0800 h, but docked cows tended to ruminate more at that time. Docked cows tended to stand less at the 1200 h observation. Total fly-avoidance behaviors were greater for all cows at the 1600-h observation. Only tail swings tended to be more frequent with docked cows, but foot stomps occurred only in the docked cows. Lymphocyte phenotypes, acute-phase proteins, and immunoglobulin concentrations did not differ. In conclusion, although docked cows were cleaner, as the fly numbers increase throughout the day, fly-avoidance behaviors also increased and foot stomping appeared as an alternative method for fly avoidance by docked cows.
(**Key words:** tail-docking, cattle, fly avoidance, behavior)

Received December 7, 2000.
Accepted March 27, 2001.
Corresponding author: S. D. Eicher; e-mail: spruiett@purdue.edu.

Abbreviation key: FITC = fluorescein isothiocyanate, **PBMC** = peripheral blood mononuclear cells.

INTRODUCTION

Tail-docking of dairy cattle continues to be an animal well-being issue in the United States. Several studies have shown that banding the tails, as a method to dock tails of adult cattle, induces few detectable behavioral or physiological indicators of pain (Eicher et al., 2000; Petrie et al., 1996). Banding followed by cutting of the necrotic tail after 7 to 14 d is a typical method to dock adult cattle. In addition to the concern about the acute pain associated with the procedure, the ability of the cow to combat flies is a well-being issue.

One of the most common types of disruptive flies in the United States is the stable fly *Stomoxys calcitrans* (Dougherty et al., 1995). The flies are the most disruptive when they are biting, which occurs with feeding when temperatures are warm enough. The feeding takes from 2 to 5 min. The flies can then remain on the animal resting or seeking a new feeding station. Typical responses of cattle to escape this intrusion are taking flight, stomping, kicking their trunk, tail swishing, the panniculus reflex (skin twitching), and head or ear movements. An economic threshold has been cited at two stable flies per foreleg (Campbell and Berry, 1989), which is set because of disruption and alterations of eating patterns and increased energy expenditure in avoidance behaviors.

New Zealand studies showed that at low fly numbers (zero) there were no differences in frequencies of fly-avoidance behaviors (such as stomping, ear twitching, and tail swings) between intact and docked cows. In environments with high fly counts (more than 20), docked cows increased avoidance behaviors that focused on the rear of the cow (Phipps et al., 1995). Fly numbers were greater on docked cows (Mathews et al., 1995; Wilson, 1976), and fly counts were greater on rear legs of cows with trimmed switches and docked cows (Mathews et al., 1995). Similarly, data showed increased fly-avoidance behaviors of docked cows. Interestingly, cows that had switches trimmed but not docked were similar to controls for tail flicks, but similar to docked cows for foot stomps. Biting flies have been linked to disrupted grazing, slower growth, reduced milk production and weight gain, and increased stress (Campbell and Berry, 1989).

With increased fly bites, cortisol concentrations and heart and respiration rates increased (Schwinghammer et al., 1987). Because cortisol can have pronounced effects on CD4, CD8, and $\gamma\delta$ T-lymphocyte markers, we might expect alterations of the peripheral circulating populations. Gamma delta cells home to epithelial tissue and are the largest circulating population in neonatal cattle (Burton and Kerli, 1996), suggesting an important role of $\gamma\delta$ t-cells in the first line of immune defense in cattle. Additionally, because cortisol exacerbates acute-phase proteins (Baumann and Gauldie, 1994; Gabay et al., 1995), we postulated that plasma acute-phase proteins and TNF-α (an acute-phase cytokine that could alter growth and production) may increase with fly bites, which may result from tail docking.

Because of the perceived increase in cleanliness, tail-docking is believed by producers to decrease mastitis and SCC, but this has not been verified. The need to wash the udder does not differ between docked, switch trimmed, or control cows (Mathews et al., 1995). More intact cows scored dirty than docked cows in an earlier study (Wilson, 1976), but dirtiness scores only tended to be different. SCC and mastitis incidence were not different for docked, trimmed, and intact cows (Mathews et al., 1995). All of these studies were on cows in a pasture system with differing fly populations than are common in much of the United States.

Our objectives were to determine stable fly *Stomoxys calcitrans* (Linn.) counts and fly avoidance and maintenance behavior differences of docked and intact cows in tie stalls during fly season, determine cleanliness differences, mastitis occurrences and SCC, and determine whether any early physiological indicators of stress such as cortisol, acute-phase responses, or altered leukocyte phenotypes were evident.

MATERIALS AND METHODS

Animals and Housing

Sixteen primiparous Holstein heifers were randomly assigned to docked or not docked (intact) treatments in a previous study. Heifers were in their first lactation and had been docked 1 mo before the estimated first calving by banding and removing the necrotic tail. All heifers were housed and managed according to Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (1999). The experimental protocol was approved by the Purdue Animal Care and Use Committee. Cows were housed in a tie-stall barn (1.32 × 1.83 m); intact cows were separated so that they were unable to touch docked cows with their tails. Docked and intact cows were housed throughout the barn to balance for barn effects. Deep gutters for waste removal (36 cm wide), were covered with a steel grate with steel rods at approximately 2.5-cm intervals (may prevent tails from direct access to manure). Each cow could touch with her nose or her tail one or two cows for social contact (access to only one cow was balanced across treatments). Stalls were bedded with mattresses and water cups were in each stall. Stalls were scraped twice daily, and gutters were flushed. Cows were fed a TMR that met or exceeded NRC requirements (NRC, 1989) twice daily in a bunk at ground level in front of the stalls. Habituation to the tie stall was for 1 wk before initiation of the 5-d experiment, and habituation to a chute in the tie-stall barn for blood collection was accomplished before starting the study by walking animals through the chute once daily for 5 d before the trial. Milk samples were collected for the 5 d of the study at the morning milking for SCC and analyzed by the Indiana DHIA Laboratory.

Fly Counts and Behavior Measures

The bloodsucking stable fly, *Stomoxys calcitrans* is a chronic problem on dairy cattle, usually feeding on the lower legs of cattle. This often causes animals to stamp their legs and switch their tails in reaction to the flies' feeding. Because of this preferred feeding area, stable fly counts were made on the legs as follows according to methods of McNeal and Campbell (1981): fly landings per 1-min observation on each leg, with observations beginning at 0800, 1200, and 1600 h on each of 5 d of observations. Each leg was observed from below the flank to the hoof. Cows were coaxed to standing before beginning of the counting period. Following completion of fly counts, we recorded maintenance, social, and fly-avoidance behaviors by direct observation for 1 h. Maintenance and social behaviors included lying, standing, eating, drinking, cow-cow interacting, and pen contact as defined previously (Eicher et al., 2000). Ruminating was defined as repeated chewing, which does not immediately follow eating behavior. Fly-avoidance behaviors were tail swings, foot stomps, panniculus reflex, and ear twitches (Dougherty et al., 1993a) plus feed tossing and head tossing. We used a 5 min interval instantaneous scan sample technique (time sampling) for 1 h so that each cow was observed for 12 scans during an hour at three time periods each day for 5 d. One cow was observed at a time, until all cows were observed for that 5-min period. The rest of the 5-min periods followed the same sequence, but the sequence of observation was randomized for each time period (0800, 1200, or 1600 h).

Cleanliness Scores

Cow cleanliness was scored by a modification of the method of Yungblut (1974). Cows were cleaned uniformly before placement in the experimental stalls. Three people scored color photos of the left rear of the cow from the front udder attachment back to the tail head, but the tail was not scored. A score of 1 was a cow that was completely clean in the area under observation. A score of 5 was given to a cow with dirt (manure) completely covering the area. The values from three observers for each cow were averaged to arrive at each cow's score for data analysis. Similarly, using a software program to crop pictures from the rear view (so that a uniform area was displayed), a view of the udder from the back was scored. A percentage of visible udder that was dirty was scored and averaged similarly to the scoring for the left rear of the cow. The interobserver variation of this procedure had a coefficient of SD of 0.86 for docked cows and 0.78 for control (no observer effects or observer by treatment interactions were found) and intra-observer SD was 0.74 and 0.83 (observation was significant, but no treatment by observation interaction was found).

Physiological Samples

Jugular vein blood samples were collected into three 10-ml heparinized Vacutainer tubes at 1300 h daily following behavior observations. Blood samples were refrigerated (4°C) until centrifuged at 700 × g for 15 min. Plasma was removed and frozen (–70°C) for later analysis of acute phase proteins (haptoglobin and α_1 acid-glycoprotein), immunoglobulin G, tumor necrosis factor-α, and cortisol concentrations. Peripheral blood mononuclear cells (**PBMC**) were harvested from the buffy coat of each sample as previously described (Blecha and Baker, 1986).

Immune Measures

Separated PBMC were counted and resuspended in Rose Park Memorial Institute media 1640 (RPMI, Sigma Chemical Co., St. Louis, MO) at 2×10^6 cells/ml. Cells were aliquoted (200 μl) into six tubes. The first tube was washed and fixed as a background control (cells only). Antibodies for specific cell surface markers were added (1.5 μl) to the subsequent four tubes for detection of CD4 (cact138A, VMRD, Pullman, WA), CD8 (cact80C, VMRD), TcR1 (86D, VMRD), and $\gamma\delta$ (anti-WC1, VMRD) T-cell populations. Primary antibodies were mouse-anti-bovine and the secondary antibody was a fluorescein isothiocyanate- (**FITC**) labeled rabbit anti-mouse IgG (Gibco, Grand Island, NY). The FITC fluorescence was used to measure lymphocyte markers by flow cytometry with a Coulter Elite flow cytometer (Hialeah, FL), using a 488-nm air cooled argon laser for excitation and a 525-band pass for FITC labels.

Alpha$_1$ acid-glycoprotein (AGP, Saikin Kagaku Institute Co., Sendai, Japan) was measured with radial immunodiffusion assay plates and haptoglobin by ELISA (Young et al., 1995). Cortisol was measured using a ^{125}I radioimmunoassay (Coat-a-count, Diagnostic Products Corp., Los Angeles. CA). Tumor necrosis factor-α was measured with a biological assay using a WEHI 164 cell line (American Type Culture Collection, Rockville, MD) as previously described (Lorence et al., 1988; Rood et al., 1990).

Statistical Analysis

Data were analyzed as a completely randomized design (physiological measures, SCC, and cleanliness scores) or as a repeated measure design (fly counts and behavior measures). Main effects and interactions were treatment and time of day and treatment × time of day. All were done within the general linear models program of SAS (1985). Data for the 5 d were averaged for analysis within the model. Behavioral (maintenance and fly avoidance) data were log or log (x + 1) transformed to normalize the distribution and homogenize variances.

RESULTS

Fly Counts

Stable flies were counted daily at 0800, 1200, and 1600 h (Figure 1). Total counts by front legs, rear legs, and total (panel A) demonstrated no significant difference in number of flies on the front of docked and intact cows. Although flies were on the rear legs of all cows, the docked cows had almost twice as many flies as the intact cows ($P < 0.01$). The increase of flies on the rear legs due to docking was also reflected in the total fly counts, resulting in a significant total fly count increase in docked cows ($P < 0.01$). When analyzed by time (0800, 1200, and 1600 h), front leg counts were not different between docked and intact cows (time × treatment interaction; $P > 0.10$). However, the rear leg fly counts were significantly greater for docked cows at 0800 ($P < 0.05$), 1200 ($P < 0.01$), and 1600 ($P < 0.05$) h.

Cleanliness Scores

Docked cows were cleaner by a full point on a five-point scale ($P < 0.05$) for the rear-quarter cleanliness (Figure 2). However, cleanliness scores for the udders were not different (data not shown). Somatic cell counts that were averaged for the 5 d were not significantly greater for the docked cows, and mastitis occurrences were too infrequent to analyze (data not shown).

Behavior Analysis

Maintenance and social behaviors include lying, standing, eating, drinking, ruminating, grooming, interactions, and pen contact (Figure 3). The only maintenance behavior that was different by treatment was cow-cow interactions ($P < 0.01$) at noon and pen contact in the morning. These were very small changes and probably not physiologically significant. There were trends ($P = 0.07$) for increased ruminating in docked cows in the morning. While there was a change from predominantly lying in the morning to predominantly standing in the afternoon, more docked cows tended to stand at noon ($P = 0.09$).

Fly-avoidance behaviors (Figure 4) were increased for docked cows in feed tossing in the afternoon, 1600 h. Tail swings were greater at 0800 h for control cows and at 1600 h tended ($P = 0.09$) to be greater for the docked cows.

Immune Cell Marker Expression and Immunoglobulin Concentrations

Lymphocyte marker data are shown in Table 1. Docked cows' CD4 and CD8 percent positive lympho-

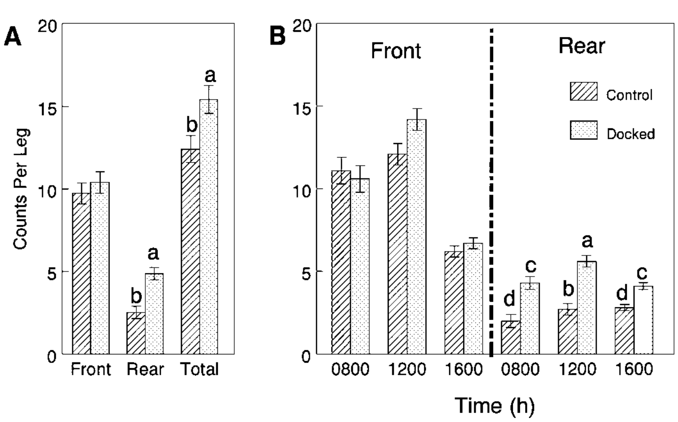

Figure 1. Mean fly counts ± SE for intact and docked heifers by front and rear legs and a total count (Panel A). Mean fly counts for front and rear legs at 0800, 1200, and 1600 h for intat and docked heifers (Panel B). [a,b]Means within time that do not share a common superscript differ ($P < 0.01$). [c,d]Means within x axis label that do not share a common superscript differ ($P < 0.05$).

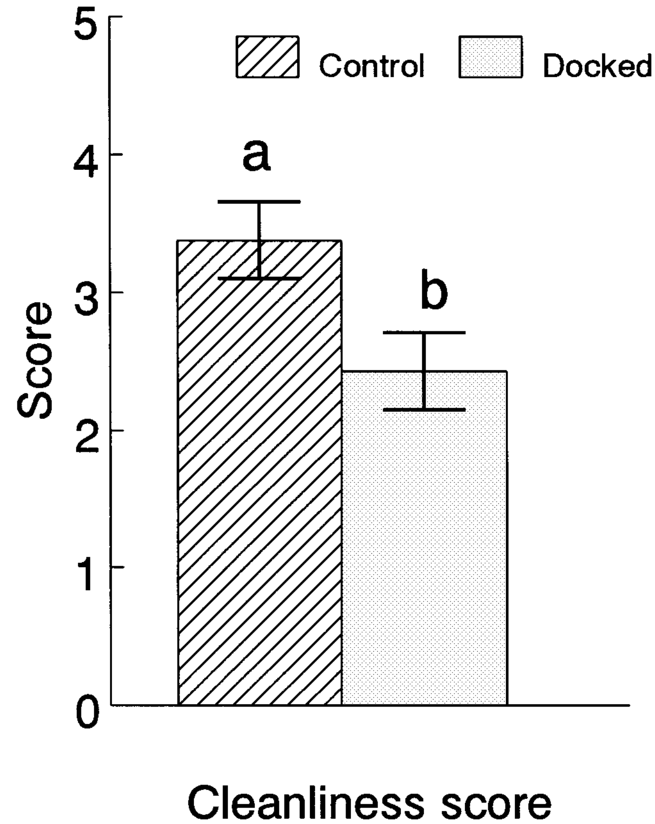

Figure 2. Mean cleanliness score ± SE on a scale of 1 = clean and 5 = dirty for docked and intact heifers. Means within a measurement that do not share a common superscript differ ($P < 0.05$).

cytes and the resulting ratio was not different than those of intact cows. Gamma delta T-cell populations were not different ($P = 0.15$) for docked cows compared with intact cows, as measured by the T-cell receptor antibody. Similarly, the WC1 antibody did not detect treatment effects. Plasma IgG was not different between treatments (Table 1). Two acute-phase proteins, haptoglobin and α_1 acid-glycoprotein, TNF-α, and cortisol were not different between treatments (Table 1).

DISCUSSION

Cow cleanliness is one of the advantages cited by dairy managers for docking cows. Scientific studies have resulted in contradictory results. Two studies were conducted on pastured cattle in New Zealand. Wilson (1976) measured cleanliness of various areas of the hindquarters of docked and intact cattle, concluding that a greater percentage of docked cows were cleaner, but udders were not cleaner. Cleanliness scores only tended to be different between docked and intact cows. This suggests that not only where we choose to measure cleanliness (left or right side), but what anatomical part is considered in the scoring may affect the outcome. Udder cleanliness (assessed by whether milkers washed the udders before milking) was not different for intact, trimmed, or docked cows (Mathews et al., 1995). A method to determine dirty areas by counting dirty squares on specific areas, did not detect differences between docked and intact cows in a western Canadian free-stall system (Tucker et al., 2001). The cows in tie-stall housing in our study were cleaner in the rear of the cow when docked, but udder cleanliness scores were not different. Docking keeps the tails out of the gutter and, therefore, the cows remain cleaner in the areas that would be swatted with a dirty tail. The difference reported from various research is hard to resolve because of different housing, including housing type, stall length, weather, water consumption and ration, frequency of cleaning, manure removal method, and access to other areas. Interestingly, this study dissolves the myth that cleaner cows will result in fewer

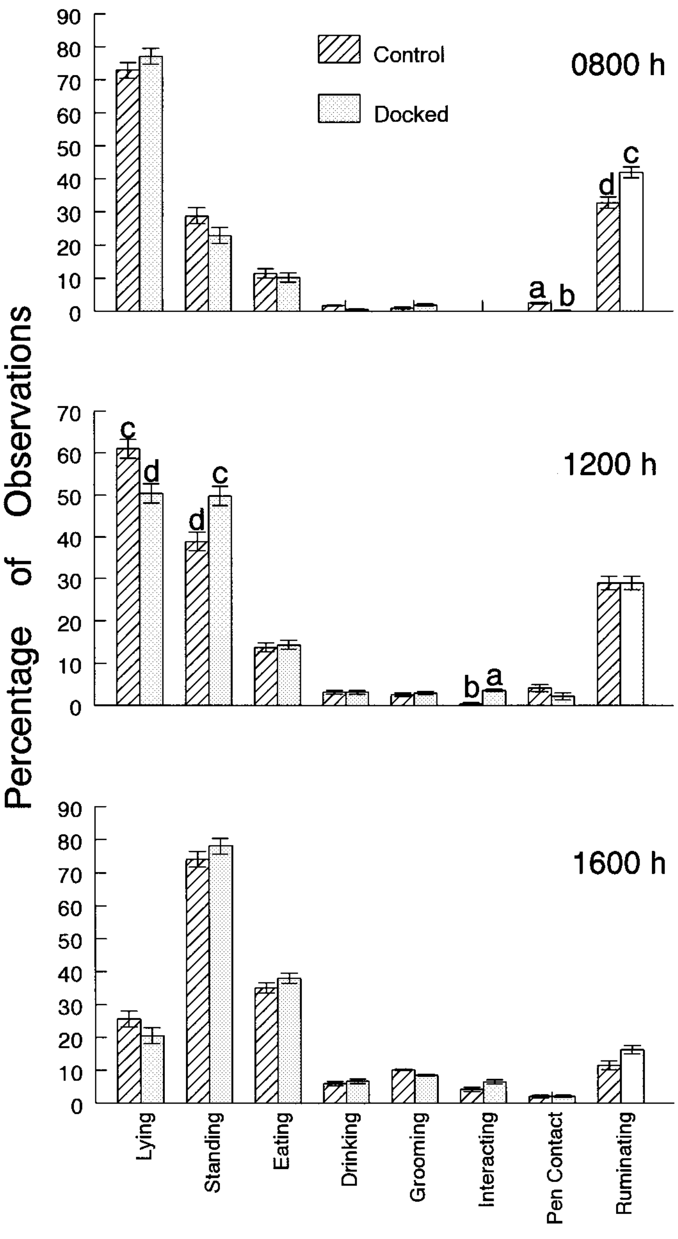

Figure 3. Maintenance behaviors ± SE expressed as a percentage of observations for intact and docked heifers and 0800, 1200, and 1600 h. Means within a behavior for 0800, 1200, or 1600 observations that do not share a common superscript differ [a,b]($P < 0.05$) and [c,d]($P < 0.10$).

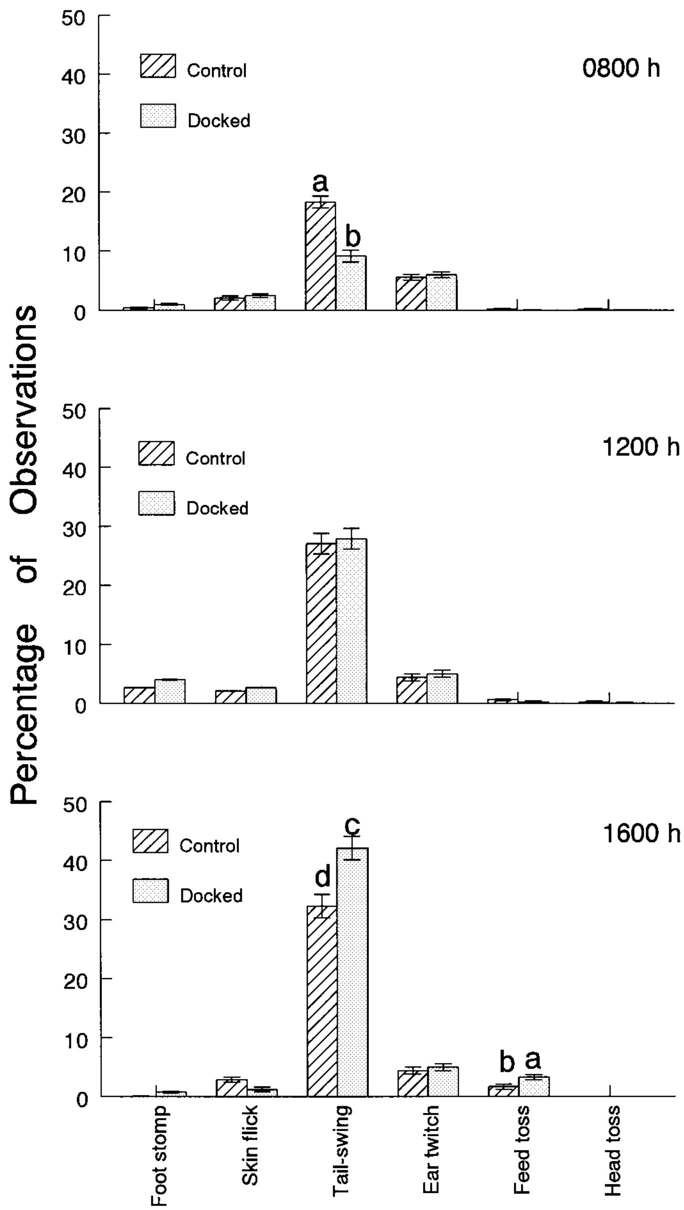

Figure 4. Fly-avoidance behaviors ± SE expressed as a percentage of observations for intact and docked heifers and 0800, 1200, and 1600 h. Means within a behavior for 0800, 1200, or 1600 observations with differing superscripts differ [a,b]($P < 0.05$) and [c,d]($P < 0.10$).

Table 1. Least squares means ± SE of plasma IgG, cortisol, tumor necrosis factor-α, acute, phase proteins, and lymphocyte phenotypes.

Response	Treatment	
	Intact	Docked
IgG (mg/ml)	10.8 ± 0.6	10.5 ± 0.6
Cortisol (NG/ml)	9.4 ± 2.2	10.1 ± 2.2
Acute-phase response		
Tumor necrosis factor-α (% kill)	11.8 ± 5.9	12.3 ± 5.9
Haptoglobin (mg %)	0 ± 11.5	74.9 ± 11.5
α_1 acid-glycoprotein (μl/ml)	360 ± 53.4	347 ± 53.4
Lymphoctyte phenotypes		
$CD4^+$ (% positive)	18.5 ± 1.6	19.4 ± 1.6
$CD8^+$ (% positive)	10.2 ± 1.1	10.4 ± 1.1
CD4:CD8 (ratio)	1.8 ± 0.2	1.9 ± 0.2
$\gamma\delta$ (% positive)	6.7 ± 1.1	8.9 ± 1.1
WC_1 (% positive)	2.4 ± 0.4	2.9 ± 0.4

flies. Rather the inability to swat the flies resulted in greater fly numbers.

Fly counts were consistent with previous studies of dairy cattle (Mathews et al, 1995; Wilson, 1976). The greatest fly counts occurred around noon, which can be explained by normal fly behavior (Ladewig and Matthews, 1992). Flies adhere to walls and other surfaces until the temperature rises, so peak activity is around noon for feeding (biting the animals). Then the flies return to rest on the walls or surface, with fewer feeding bouts (Dougherty et al., 1995). Stable flies tend to land on the legs and sides of cattle, in contrast to the face fly that bites the face and legs on pastures. Fly counts of cattle on pasture showed increased fly numbers on the rear of docked cows and increased fly-avoidance behaviors at 1200 and 1500, but not at 0700 (Phipps et al., 1995).

Fly-avoidance behaviors reflected the increased fly counts, thus these behaviors were greatest in docked cows. The counts and behaviors that increased were both specific for rear of the cow. As shown by control cows, fly-avoidance behaviors, such as swatting with the tail, were able to alleviate fly numbers. Biting flies have been linked to disrupted grazing, slower growth, reduced milk production and weight gain, and increased stress (Campbell and Berry, 1989). Fly-avoidance behaviors of beef cattle, including head and ear movements, panniculus reflex, and tail swings, increased linearly with increased numbers of released flies (Dougherty et al., 1993b, 1994). Feed intake, surprisingly, also increased linearly with increased flies released. We found no significant feeding effects with fly counts at 12 to 15 per leg, which is similar to total fly counts of Dougherty (1995) when 50 stable flies were released periodically. However, the flies in our study were predominantly stable flies, which were shown not to be detrimental to milk production in an early study (Freeborn et al., 1928). Tail swings were the most frequent fly-avoidance behavior recorded during our observations, similar to the results of Dougherty et al. (1994 and 1995), Todd (1964), and Phipps (1995).

The observed increase of lying and ruminating during the morning of docked cows was during low fly counts. Ruminating is often associated with lying and together presumed to be an indicator of a comfortable cow (Albright and Arave, 1997). Lying could also be a responsible for a lack of tail-swing occurrences and decreased pen contact by docked cows in the morning observations. Docked cows stood more than intact cows when the fly numbers increased in our study. This could indicate that cows are uncomfortable, because cows tend to stand when uncomfortable.

Although other studies have shown physiological responses to acute and chronic stable fly exposure (Schwinghammer et al, 1987), others have demonstrated no effect of intermittent exposure to varying numbers of stable flies (Estienne et al., 1991). We saw a numerical, but not significant, increase in gamma delta T-cell populations. Our data were collected under wild fly population numbers and do not reflect an acute, but a low chronic fly population. Increased gamma-delta cells are an expected response to constant skin irritants such as fly bites. Limited data is available on effects of flies on immune parameters. Moire et al. (1997) determined a protease produced by the parasitic warble-fly larva is responsible for inhibition of lymphocyte proliferation in cattle. Nicolas-Gaulard et al. (1995) showed that the protease enzyme is also responsible for decreased interleukin-2 production and therefore reduced lymphocyte blastogenesis. This is consistent with our results showing a skewing of the lymphocyte population toward cytotoxic cells rather than helper T-cells.

Several studies point to decreased milk yield associated with fly bites (Jonsson and Mayer, 1999; Minar et al., 1987). Jonsson and Mayer (1999) predicted a threshold number of flies (n = 30) below which no adverse effects on milk yield or weight gain could be detected by analyzing existing literature data. The cumulative effects of docking over time prevented a good comparison of yield under the design of this particular trial. Cattle appear to cope with fly populations, particularly low fly concentrations, as seen in most dairies. However, it is clear that fly numbers increase on the rear legs of cattle with docked tails in all housing systems examined to date. Therefore if it is necessary to dock cows, then particular attention to fly control is essential.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Cheryl Towell (fly counts), Alan Kauffman (laboratory analysis), Kerry Whitehead (behavior observations and fly counts), and Jeff Dailey (behavior technical assistance). We also thank the Purdue Dairy Teaching and Research Center personnel for their cooperation.

REFERENCES

Albright, J. L., and C. W. Arave. 1997. Pages 123–126 *in* The Behavior of Cattle. CAB International, New York, NY.

Baumann, H., and J. Gauldie. 1994. The acute phase response. Immunol. Today 15:74–80.

Blecha, F., and P. E. Baker. 1986. Effect of cortisol in vitro and in vivo on production of bovine interleukin 2. Am. J. Vet. Res. 47:841–845.

Burton, J. L., and M. E. Kehrli, Jr. 1966. Effects of dexamethasone on bovine circulating T lymphocyte populations. J. Leukoc. Biol. 59:90–99.

Campbell, J. B., and I. L. Berry. 1989. Economic threshold for stable flies on confined livestock. Misc. Publ. Entomol. Soc. Am. No. 74:18–22.

Dougherty, C. T., F. W. Knapp, P. B. Burrus, D. C. Willis, P. L. Cornelius, and N. W. Bradley. 1993a. Multiple releases of stable flies (*Stomoxys calcitrans L.*) and behaviour of grazing beef cattle. Appl. Anim. Behav. Sci. 38:191–212.

Dougherty, C. T., F. W. Knapp, P. B. Burrus, P. B., D. C. Willis, and N. W. Bradley. 1993b. Face flies *Musca autumnalis* De Geer) and the behavior of grazing beef cattle. Appl. Anim. Behav. Sci. 35:313–326.

Dougherty, C. T., F. W. Knapp, P. B. Burrus, D. C. Willis, and P. L. Cornelius. 1994. Moderation of grazing behavior of beef cattle by stable flies (*Stomoxys calcitrans* L.). Appl. Anim. Behav. Sci. 40:113–127.

Dougherty, C. T., F. W. Knapp, P. B. Burrus, D. C. Willis, and P. L. Cornelius. 1995. Behavior of grazing cattle exposed to small populations of stable flies (*Stomoxys calcitrans L.*). Appl. Anim. Behav. Sci. 42:231–248.

Eicher, S. D., J. L. Morrow-Tesch, J. L. Albright, J. W. Dailey, C. R. Young, and L. H. Stanker. 2000. Tail-docking influences on behavioral, immunological, and endocrine responses in dairy heifers. J. Dairy Sci. 83:1–7.

Estienne, M. J., F. W. Knapp, J. A. Boling, and J. G. Burg. 1991. Physiological and nutritional responses of beef steers exposed to stable flies (Diptera: Muscidae). J. Econ. Entomol. 84:1262–1265.

Gabay, C., B. Genin, G. Mentha, P.B. Iynedjian, P. Roux-Lombard, and P.A. Guerne. 1995. IL-1 receptor antagonist (IL-1Ra) does not inhibit the production of C-reactive protein or serum amyloid A protein by human primary hepatocytes. Differential regulation in normal and tumour cells. Clin. Exp. Immunol. 100:306–313.

Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching, 1st rev. ed. 1999. Federation of Animal Science Societies, Savoy, IL.

Freeborn, S. B., W. M. Regan, and A. H. Folger. 1928. The relation of flies and fly sprays to milk production. J. Econ. Entomol. 32:494–501.

Jonsson, N. N., and D. G. Mayer. 1999. Estimation of the effects of buffalo fly (*Haematobia irritans* exigua) on the milk production of dairy cattle based on a meta-analysis of literature data. Med. Vet. Entomol. 13:372–376.

Ladewig, J., and L. R. Matthews. 1992. The importance of physiological measurements in farm animal stress research. Proc. N.Z. Soc. Anim. Prot. 52:77–79.

Lorence, R., P. A. Rood, and K. W. Kelley. 1988. Newcastle disease virus as an anti-neoplastic agent: induction of tumor necrosis factor-α and augmentation of its cytotoxicity. J. Natl. Cancer Inst. 80:1305–1308.

Mathews, L. R., A. Phipps, G. A. Verkerk, D. Hart, J. N. Crockford, J. F. Carragher, and R. G. Harcourt. 1995. The effects of taildocking and trimming on milker comfort and dairy cattle health, welfare and production. Pages 1–25 *in* Animal Behaviour and Welfare Research Center, Hamilton, NM.

McNeal, C. D., Jr., and J. B. Campbell. 1981. Insect pest management in Nebraska feedlots and dairies: a pilot integrated pest management project. Dep. Entom. Rep. 10, University of Nebraska. 43 pp.

Minar, J., L. A. Kostenko, and J. Riha. 1987. Decrease in the milk yield in cows caused by dipterous blood-sucking insects and the protection of heifers with Oxamate, a repellent, in the area of Leningrad. Vet. Med. 32:355–63.

Moire, N., I. Nicolar-Gaulard, Y. Le Vern, and C. Boulard. 1997. Enzymatic effect of hypodermin A, a parasite protease, on bovine lymphocyte membrane antigens. Parasite Immunol. 19:1–7.

National Research Council. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. ed. Natl. Acad. Sci., Washington, DC.

Nicolas-Gaulard, I., N. Moire, and C, Boulard. 1995. Effect of the parasite enzyme, hypodermin A, on bovine lymphocyte proliferation and interleukin-2 production via the prostaglandin pathway. Immunology 85:160–165.

Petrie, N. J., D. J. Mellor, K. J. Stafford, R. A. Bruce, and R. N. Ward. 1996. Cortisol responses of calves to two methods of tail docking used with or without local anaesthetic. N.Z. Vet. J. 44:4–8.

Phipps, A. M., L. R. Matthews, and G. A. Verkerk. 1995. Tail docked dairy cattle: fly induced behaviour and adrenal responsiveness to ACTH. Proc. N.Z. Soc. Anim. Prod. 55:61–63.

Rood, P. A., R. M. Lorence, and K. W. Kelley. 1990. Serum protease inhibitor abrogation of Newcastle disease virus enhancement of cytolysis by recombinant tumor necrosis factor alpha and beta. J. Natl. Cancer Inst. 82:213–218.

SAS User's Guide: Statistics, Version 5 Edition. 1985. SAS Inst., Inc., Cary, NC.

Schwinghammer, K. A., F. W. Knapp, and J. A. Boling. 1987. Physiological and nutritional response of beef steers to combined infestations of horn fly and stable fly (Diptera: Muscidae). J. Econ. Entomol. 80:120–125.

Todd, D. H. 1964. The biting fly (*Stomoxys calcitrans* L.) In dairy herds in New Zealand. N.Z. J. Agric. Res. 7:60–79.

Tucker, C. B., D. Fraser, and D. M. Weary. 2001. Tail docking dairy cattle: effects on cow cleanliness and udder health. J. Dairy Sci. 84:84–87.

Wilson, G. D. A. 1972. Docking cows' tails. Pages 158–165 *in* Ruakura Farmers Conference, Ruakura, New Zealand.

Young, C. R., P. D. Eckersall, P. D. Saini, and L. H. Stanker. 1995. Validation of immunoassays for bovine haptoglobin. Vet. Immunol. Immunopathol. 49:1–13.

Yungblut, D. H. 1974. The effect of different types of freestall housing upon dairy cattle health, production, behavior, and milk quality. M.S. Thesis, Purdue University, West Lafayette, IN.